

# Observed Changes in Phenology Across the United States - Southwest

## California, Nevada, Utah, Colorado, Arizona, and New Mexico

### Background

Phenology — the seasonal timing of life cycle events in plants and animals such as flowering, hibernation, and migration — has been linked to shifts in the timing of allergy seasons, public visitation to National Parks, and cultural festivals. Change in phenology, recognized as a bio-indicator of climate change impacts, has also been linked to increased wildfire activity and pest outbreak, shifts in species distributions, spread of invasive species, and changes in carbon cycling in forests. Phenological information can and already is being used to identify species vulnerable to climate change, to generate computer models of carbon sequestration, to manage invasive species, to forecast seasonal allergens, and to track disease vectors, such as mosquitoes and ticks, in human population centers.



“Timing of snowmelt in the alpine and timing of precipitation in the desert are key phenological drivers in the Southwest.”

**This is one in a series of eight, geographic region-focused information sheets that summarizes documented changes in plant and animal phenology over the past century across the United States.** This summary is based on long-term studies (10 years or more) published in the primary scientific literature since 2001. A forthcoming manuscript synthesizes the findings of the eight regional information sheets.

This information was developed in support of the U.S. Global Change Research Program’s **National Climate Assessment** and can be used to facilitate preparation for the cascading effects of ongoing climate change.

### The Southwest

The western and southwestern regions of the U.S. consist of a variety of biomes, ranging from deserts and coastal areas to mountains and forested regions [1, 2]. Climate also varies widely, ranging from Mediterranean and semi-arid steppe, to mid-latitude desert and alpine. This region is considered a biodiversity “hot spot” in terms of the number of endemic species [3]. Temperatures in the Southwest have increased more than other regions in the continental U.S. [1, 2]. Drought is also an important component of the climatic landscape of the Southwest. Major droughts, including those described as ‘mega-droughts,’ can persist for long durations and are expected to become more severe in the future [4]. The human population in this region has nearly quadrupled since 1950, increasing competition for already over-allocated water resources [1, 2].

### Changes in Phenology - Highlights

#### *Spring flight of butterflies advances by nearly one month*

In California’s Central Valley, 70% of 23 butterfly species displayed a trend towards earlier spring flights over the past 31 years, with one species advancing nearly one month. Higher maximum temperatures in winter and drier winters were correlated with the earlier appearance of these butterflies [5].

#### *Earlier snowmelt in the Rocky Mountains influences timing of blooming*

For certain subalpine wildflowers in the Rocky Mountains in Colorado, earlier snowmelt was linked to earlier blooming. Subsequently, earlier blooming led to greater susceptibility to late-season frost damage in aspen sunflower (*Helianthella quinqueremis*) [6]. Glacier lily (*Erythronium grandiflorum*), bloomed earlier (3.2 days/decade) over a 30-year period in Colorado. The study linked earlier snowmelt and greater summer precipitation in the previous year to earlier blooming [7]. Winter and spring dust deposition from deserts on snow promotes snowmelt, similar to

the effects of warming temperatures. In contrast to conditions in which warming accelerates snowmelt and flowering time, some alpine wildflowers respond to dust deposition by delaying the onset of spring growth and flowering [8]. The authors suggested that this will affect ecological processes and interactions across the alpine landscape, including competition for pollinators [8]. A separate study indicated that warmer, drier conditions linked to changes in climate will likely increase desert dust deposition on alpine snow [9].

#### ***Yellow-bellied marmots emerge earlier from hibernation***

Yellow-bellied marmots (*Marmota flaviventris*) observed over 33 years (1976–2008) in Colorado emerged earlier from hibernation, and gave birth earlier in the season. This change gave marmots more time to grow before the end of the season. As a result, marmots tended to have larger body sizes at the beginning of hibernation than two decades ago. Larger body size is associated with lower mortality rates and higher population sizes. The increase in the length of the growing season associated with climate change may have strong effects on the individual health and population size of these small mammals [10].

#### ***Shifts in the arrival times of long-distance migrant birds documented***

In northern California, 13 of 21 species of Nearctic-Neotropical birds showed a change in arrival time, with eight species arriving earlier, two later, and three with a mixed response at different sites. This study linked shifts in arrival to changes in temperature and natural variability in climate [11].

#### ***Hummingbirds may become mismatched with food sources***

Researchers in Arizona and Colorado found that nectar plants along the spring migration route of broad-tailed hummingbirds (*Selasphorus platycercus*) are advancing peak flowering with increased latitude, resulting in a shorter time interval between first bird arrivals and first flowers at the northern end of their breeding range. This could reduce the hummingbirds' nesting success in high-latitude breeding grounds with current rates of warming-induced shifts in phenology [12].

#### ***Hotter and drier conditions affect desert plants***

At a field site in the Sonoran Desert, mean annual precipitation decreased while mean annual temperatures increased during the growing season over a 25-year period. However, a study of desert annuals found that germination actually occurred under colder conditions due to delays in the occurrence of winter rains, which now peak in December rather than October. This shift in the timing of rainfall led to an increase in abundance of cold-adapted plant species in that they were able to germinate successfully in cool conditions [13]. Researchers created a phenological model using information on the physiological requirements of desert shrubs coupled with temperature and precipitation data to estimate advancement in flowering over a 110-year period. To test the

validity of the predicted 20–41 day advancement, researchers extracted blooming time information from herbarium records collected during this same time period, ultimately confirming predictions of the models. In particular, a greater proportion of plants bloomed in March instead of May during the last 10 years of the study when compared with the first 10 years [14].

#### ***Type of vegetation is important for evaluating phenology on a landscape scale***

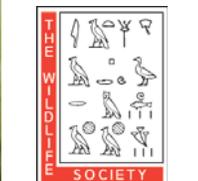
Analyses of remotely-sensed data from the Great Basin Desert indicated that phenological changes vary according to vegetation type (e.g., grasses, sagebrush). Vegetation was sensitive to inter-annual changes in climate and, while there was no long-term trend, the changes in phenology of the vegetation types in response to moisture (especially in very wet or dry years) suggested that vegetation would be sensitive to climatic changes on a long-term scale. The researchers stated that additional data beyond the 10 years they examined would be necessary to evaluate long-term trends in phenology [15].

#### **Case Study: Changes in Plant Communities in the Sky Islands Region of the Southwest**

Researchers examined a 20-year dataset in southeastern Arizona across a 1200 m elevation gradient to determine whether local plant communities have changed over time [16]. Out of 363 plant species studied since 1984, 93 (25.6%) showed a significant shift upward in the lowest elevation at which they flowered. Furthermore, there was an expansion in flowering range of some species into higher elevations, a pattern consistent with expectations under increased summer warming. In a related study of the same dataset, researchers found that only 10% of the total species exhibited a trend toward earlier spring blooming. The drivers of bloom time were diverse, with a general trend of plants at lower elevations showing a delay of spring flowering when insufficient chilling or moisture occurred the previous autumn, and those same species blooming earlier at higher elevations with warmer spring temperatures. With future warmer and drier conditions, plants at lower elevations are expected to experience delayed flowering if the timing or amount of rain is altered, or if it is too warm for plants to experience sufficient winter chilling, whereas plants at higher elevations are expected to advance blooming with increased temperatures [17]. In contrast, additional research found that onset of flowering in summer is strongly linked to the amount and timing of July 'monsoon' rains across elevations and plant life forms [18]. As a result, with projected future drying in the Southwest, species across elevations are predicted to flower later in summer due to decreased soil moisture conditions resulting from increased summer temperatures; this could affect food resources for pollinators that don't change their visitation times to match these plants.

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